

**MISSION OVERVIEW**

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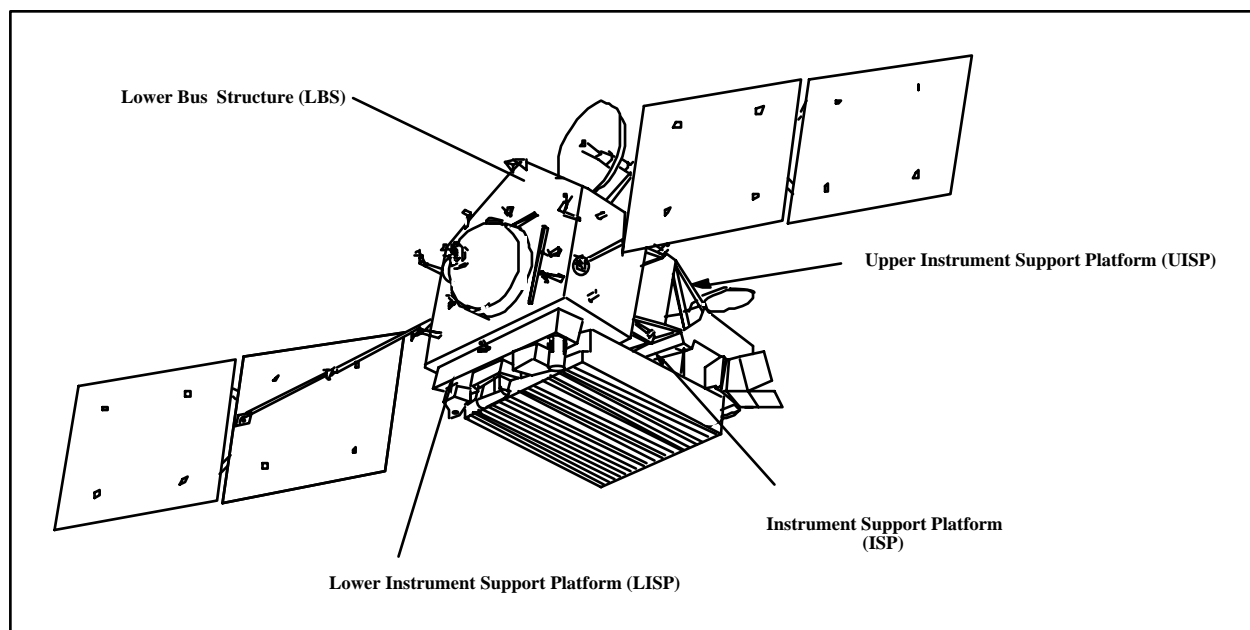
**2. MISSION OVERVIEW**

The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between the National Aeronautics and Space Administration (NASA) of the United States and the National Space Development Agency (NASDA) of Japan. TRMM is one of a series of missions within the NASA Earth Probe Satellite Program planned for the mid 1990's. For NASDA, the TRMM is one of the missions of NASDA's Earth Observation Program. In November 1997, the TRMM observatory will be placed into orbit by a Japanese H-II Expendable Launch Vehicle (ELV) from the Yoshinobu Launch Complex (YLC), Tanegashima Space Center (TnSC), Japan. The H-II will release TRMM directly into a 380 km ( $\pm 10$  km) circular orbit inclined  $35^\circ$  to the equator. The TRMM will be lowered to the mission altitude of 350 km via a combination of orbit adjust maneuvers and atmospheric drag. Prior to and upon reaching the mission altitude, a series of spacecraft and instrument checkout activities will commence.

TRMM is a three-axis stabilized spacecraft, nadir pointing for instrument observation of the Earth and its atmosphere, with the X-axis aligned with the velocity vector. In its final mission configuration with appendages deployed, the TRMM observatory will measure approximately 5.18 meters in length, 13.41 meters in width (with solar arrays deployed), and 3.66 meters in height, with a mass of approximately 3620 kg. The TRMM spacecraft will consists of the following primary structure components:

- a. Upper Instrument Support Platform (UISP)
- b. Instrument Support Platform (ISP)
- c. Lower Instrument Support Platform (LISP)
- d. Lower Bus Structure (LBS)

Figure 2-1 provides an illustration of the TRMM spacecraft structure assembly.



**Figure 2-1 TRMM Structure Assembly**

The TRMM science instrument complement is comprised of the Precipitation Radar (PR) provided by NASDA, the Visible and Infrared Scanner (VIRS) provided by HUGHES, Santa Barbara Research Center, the TRMM Microwave Imager (TMI) provided by HUGHES Space and Communication Company, the Clouds and Earth's Radiant Energy System (CERES) provided by the Langley Research Center (LaRC) and the Lightning Imaging Sensor (LIS) provided by the Marshall Space Flight Center (MSFC). Integration and Testing (I&T) of the science instruments and the observatory housekeeping subsystems will be accomplished at Goddard Space Flight Center (GSFC) by the Engineering Directorate, Code 700.

TRMM's science and housekeeping data will be recorded continuously on-board in a Solid State Recorder (SSR). Routine downlink of TRMM telemetry will be through NASA's Tracking and Data Relay Satellite System (TDRSS). TRMM will utilize the TDRSS S-band Single Access (SSA) service every orbit for observatory health and status monitoring, recorder playback, and ranging operations. In addition to the TDRS network, L&IOC and contingency support will also be available through the following:

- a. Jet Propulsion Laboratory's (JPLs) Deep Space Network (DSN)
- b. Santiago (AGO), Chile
- c. Wallops Flight Facility (WFF)
- d. Ground Network (GN)

Real-time telemetry will be relayed by the White Sands Complex (WSC) to the TRMM Mission Operations Center (MOC) and the Sensor Data Processing Facility (SDPF) located at GSFC. The MOC will provide the systems necessary to allow the Flight Operations Team (FOT) to accomplish real-time observatory command and control, routine health and status monitoring,

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and long-term trend and performance analysis of the spacecraft housekeeping systems. The SDPF will provide Level-0 processing to the MOC and Quicklook and Level-0 processing and distribution to the TSDIS, LaRC, MSFC, and the NASDA Earth Observation Center (EOC). The TSDIS will be the focal point for TMI and VIRS instrument operations and will provide the systems necessary to allow real-time instrument status and performance monitoring. LaRC and MSFC will be the focal point for CERES and LIS instrument operations, respectively, and will provide the systems necessary to allow real-time instrument status and performance monitoring. The NASDA EOC will be the focal point for PR instrument operations and will provide the systems necessary to allow instrument status and performance monitoring.

### **2.1 MISSION OBJECTIVES**

The primary objective of the mission is to build, launch, and operate an observatory capable of obtaining multi-year monthly average rainfall data sets. Equally important objectives include the following:

- a. Operate the observatory for a minimum of 3 years.
- b. Design and develop a TRMM science data processing and information system to gather and analyze data acquired from the TRMM instruments and Ground Validation Sites (GVS).
- c. Investigate the distribution and variability of both intra-cloud and cloud-to-ground lightning and correlate the data with global rates, amounts, distribution of precipitation, and the release and transport of latent heat.
- d. Provide distribution support and equal access to selected TRMM mission data to designated Japanese and U.S. agencies and individual investigators.
- e. Combine the GVS rainfall data and the acquired space-based TRMM science data into a TRMM DataBase within the science data processing and information system.
- f. Promote research and technology transfer of results from the TRMM instrument complement with the Earth Probe Satellite Program and Earth Observing System (EOS).

### **2.2 MISSION OPERATIONS PHASES**

The TRMM operations life cycle spans from the early planning stages before launch to on-orbit mission operations, and ends with the safe ocean disposal of the TRMM observatory. The duration of the Normal Mission Operations phase is heavily dependent upon the solar cycle. TRMM mission operations will be planned around four mission phases, each having its own success criteria and focus. These phases are illustrated in Figure 2.2-1 and are as follows:

- a. Pre-launch Planning and Testing
- b. Launch and In Orbit Checkout
- c. Normal Mission Operations
- d. End-of-Life (EOL) Ocean Disposal

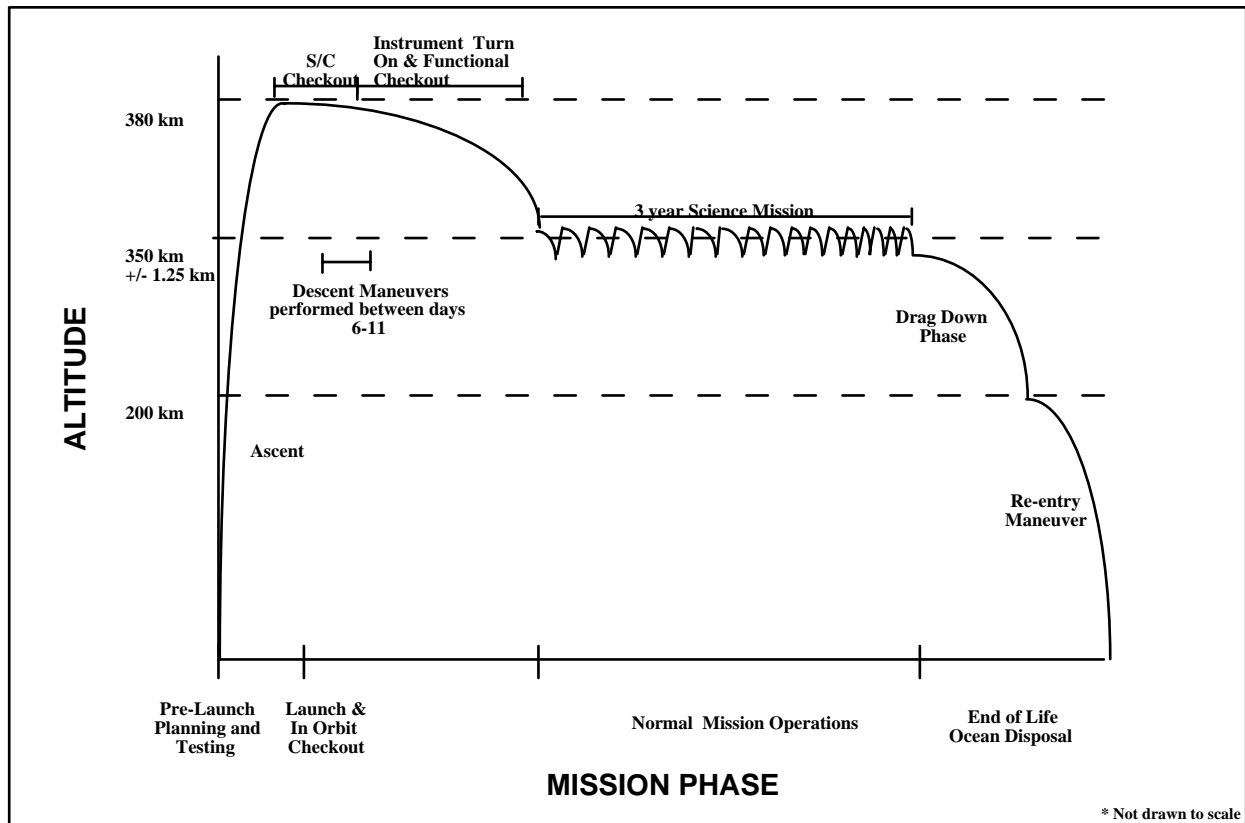


Figure 2.2-1 TRMM Mission Operations Phases

**2.2.1 Pre-launch Planning and Testing Phase**

The Pre-launch Planning and Testing phase emphasizes ground segment implementation, testing, and flight operations planning. This phase also includes activities required for final observatory checkout and launch site operations. Operations success criteria during this phase include but are not limited to the following:

- a. Complete documentation of the GDS requirements.
- b. Development and maintenance of TRMM Project Data Base (PDB) and distribution to the MOC and TRMM TTS.
- c. Development of TTTS and other test tools required for GDS testing and FOT training.
- d. Development of the TRMM Flight Operations Plan (FOP).
- e. User acceptance testing of ground segment elements, with primary focus on the MOC hardware and software systems.
- f. Staffing, training, and certification of the FOT.
- g. Development of detailed flight procedures (both normal mission and contingency operations) and MOC displays.
- h. Presentation of Mission Operations Review (MOR).
- i. Successful completion of scheduled End-to-End tests involving all operational ground systems with the TRMM spacecraft.
- j. Certification of an 'Operations Ready' ground segment via the Operations Readiness Review (ORR).
- k. Completion of the TRMM Launch and In Orbit Checkout Plan.
- l. Presentation of L&IOC checkout plan at the Flight Operations Review (FOR).
- m. Certification of a 'Launch Ready' ground and space segment via the Flight Readiness Review (FRR).
- n. Development and testing of flight procedures required for on-orbit mission operations.
- o. TRMM observatory transport from GSFC to TnSC.
- p. Observatory checkout, end-to-end testing, and launch rehearsal from launch site.

**2.2.2 Launch and In Orbit Checkout Phase**

The L&IOC Operations phase begins at launch and extends approximately 30 - 45 days. The emphasis during this phase is on TRMM launch, deployment and stabilization, spacecraft checkout, orbit descent to mission altitude, and instrument power ON and calibration. Operations success criteria during this phase include, but are not limited to the following:

- a. H-II launch, orbit insertion and TRMM payload separation.
- b. TRMM sequencer control of ACS activation, Solar Array (SA) and High Gain Antenna (HGA) deployment, and transmitter turn-on.
- c. Sun Acquisition
- d. Initial TRMM real-time telemetry acquisition by TDRS via TRMM Omni antennas.

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- e. Initial orbit determination.
- f. ACS sensor calibration including Earth Sensor Assembly (ESA) and Inertial Reference Units (IRUs).
- g. Transponder center frequency determined to within  $\pm 1500$  Hertz (Hz) of TDRS acquisition threshold.
- h. Spacecraft Frequency Standard (master oscillator) drift characterization and initial clock adjustments.
- i. Earth and Yaw Acquisition.
- j. Complete functional checkout of spacecraft systems.
- k. Orbit descent to 350 km.
- l. Instrument turn-on and functional performance checkout.
- m. Verification of initial Delta-V and  $180^\circ$  yaw maneuver capabilities.

### 2.2.3 Normal Mission Operations Phase

The Normal Mission Operations phase is the primary mission phase and should span at least three years. The point at which mission operations will transition to this phase is approximately 30 to 45 days after launch, with Launch scheduled to occur in November 1997. It is during this phase that science data is collected. Section 4 provides a more detailed description of the Normal Mission Operations phase.

### 2.2.4 End of Life Ocean Disposal Phase

The End of Life Ocean Disposal phase is the last phase of the mission. Since TRMM will be in such a low orbit ( $350 \pm 1.25$  km), orbit maintenance will be a major factor in routine operations. TRMM will be launched with approximately 890 kg of hydrazine. At some time during the mission, when approximately 58 kg of fuel is remaining, a decision will be made to terminate the mission. At that time, a controlled re-entry will be performed by the Attitude Control and Reaction Control Subsystems. More definitive details with respect to the EOL Ocean Disposal phase of the mission are discussed in section 3.4.

## 2.3 SPACECRAFT OVERVIEW

The TRMM Observatory is comprised of a main body structure, eight housekeeping subsystems, and five science instruments. This section will provide a brief overview of the TRMM spacecraft subsystems. A detailed description of the spacecraft structure will not be addressed in this document. The subsystems that comprise the TRMM spacecraft are as follows:

- a. Command and Data Handling (C&DH) Subsystem
- b. Attitude Control Subsystem (ACS)
- c. Electrical Subsystem
- d. Power Subsystem
- e. Radio Frequency (RF) Communications Subsystem
- f. Thermal Subsystem
- g. Reaction Control Subsystem (RCS)

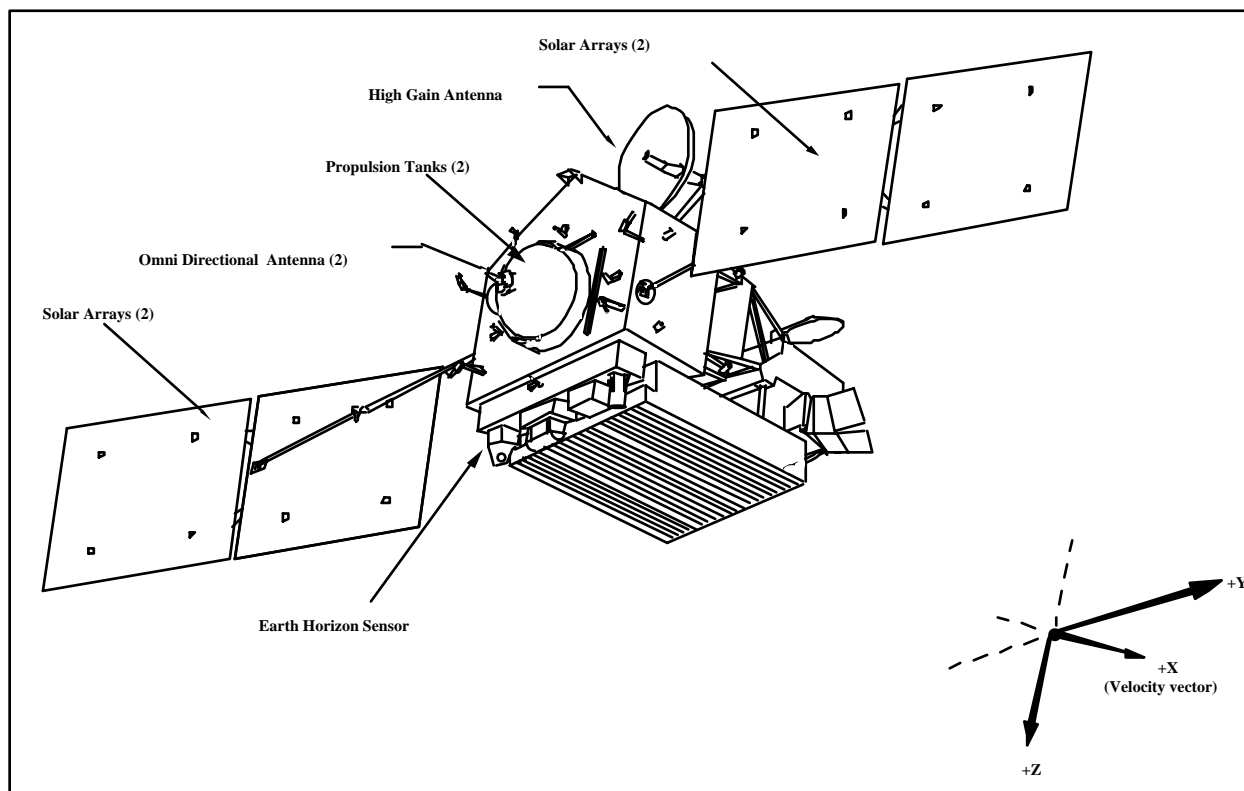
## h. Deployables

Figure 2.3-1 provides a graphical description of the TRMM spacecraft.

**2.3.1 Command and Data Handling Subsystem**

The C&DH subsystem provides redundant hardware and the software necessary to ingest, validate, and distribute commands, various S/C clocks needed to meet all timing requirements, execution of time tagged commands, onboard data storage, and a capability to store commands and tables. The C&DH also provides dual telemetry output, I- and Q-Channels and various telemetry encoding schemes (Reed-Solomon {R-S}, Cyclic Redundancy Checks {CRC}, and Convolutional Encoding). The C&DH consist of two strings designated as prime and redundant. Each string will include the following components:

- a. Uplink card
- b. Downlink card
- c. Clock card
- d. Spacecraft Processor
- e. ACS Processor
- f. 2.2 Gbits of memory



**Figure 2.3-1 TRMM Spacecraft**

Data storage of approximately 215 minutes will be provided by the C&DH subsystem in the form of solid state recorders (Bulk Memory Cards). Operations of the C&DH subsystem are described in section 4.1. Figure 2.3-2 provides a block diagram of the TRMM C&DH subsystem.

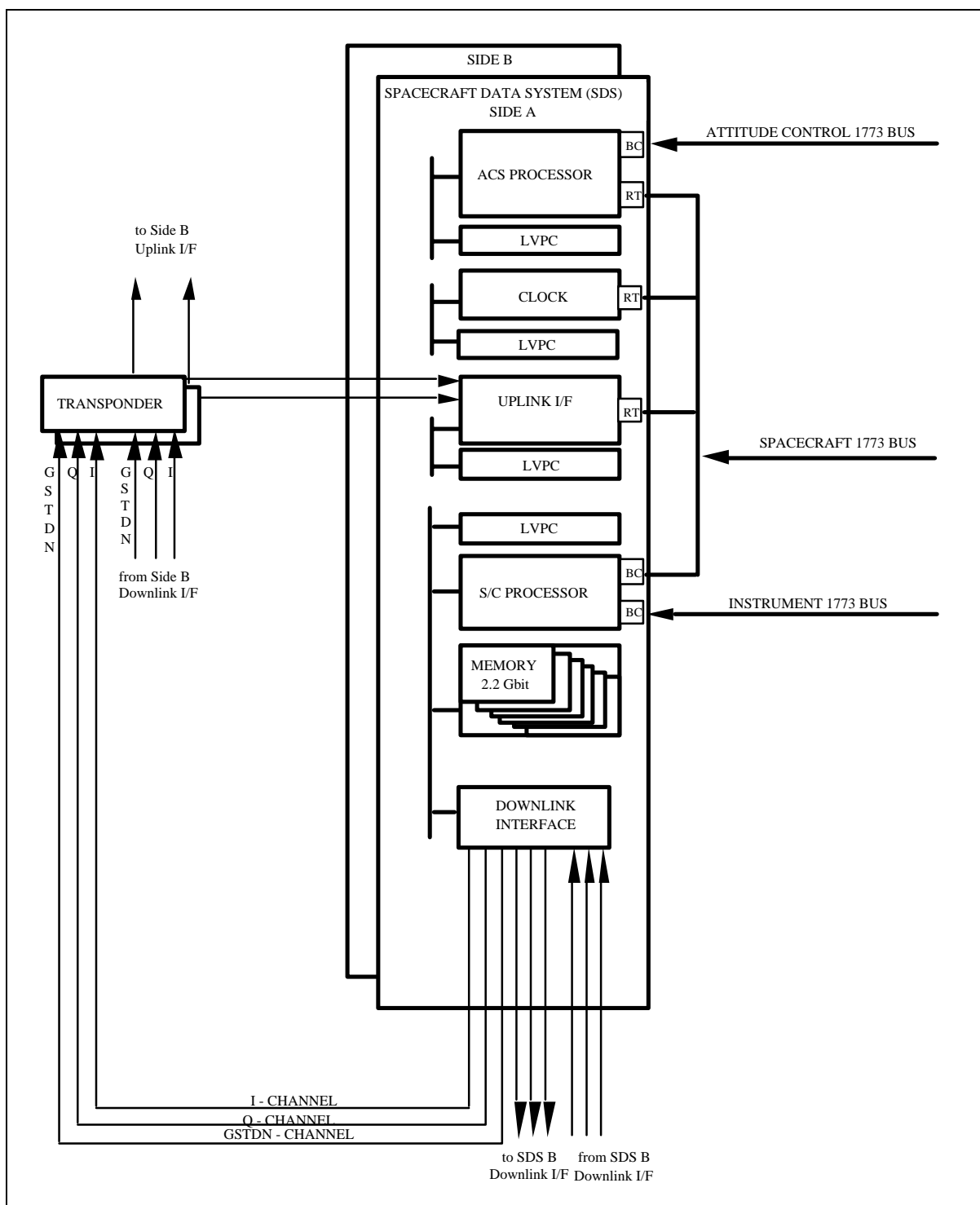


Figure 2.3-2 C&amp;DH Subsystem Block Diagram

### 2.3.2 Attitude Control Subsystem

The ACS provides autonomous control of the observatory and maintains pointing control to  $0.4^\circ$  and pointing knowledge to  $0.2^\circ$ . Redundant hardware and software is provided to meet the science objectives. The ACS consists of an Inertial Reference Unit (IRU) with three two-axis gyros, two Three Axis Magnetometers (TAM), two Coarse Sun Sensor (CSS) units (8 sensors total), two two-axis Digital Sun Sensor (DSS) units, three dual-wound Magnetic Torque Bars (MTBs), a single Earth Sensor Assembly (ESA), a prime and backup Attitude Control Electronics (ACE), four Reaction Wheel Assemblies (RWA), a prime and redundant ACS Processor (housed in the FDS), and an Engine/Valve Driver (EVD). The Gimbal and Solar Array Control Electronics (GSACE) controls the High Gain Antenna System (HGAS) and the Solar Array Drive Assemblies (SADA).

Details of the ACS are provided in Section 4.2. Figure 2.3-3 provides a block diagram of the ACS.

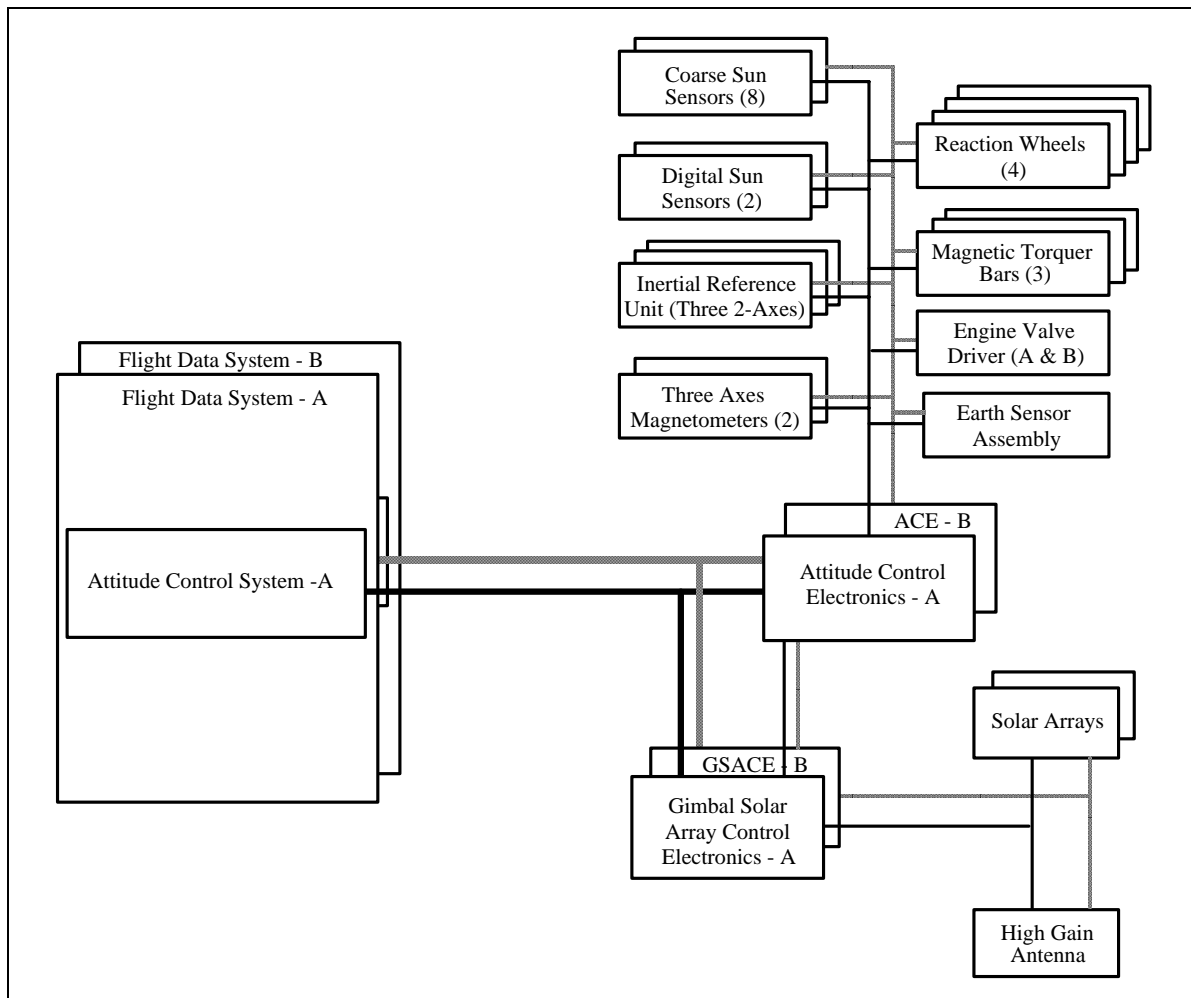
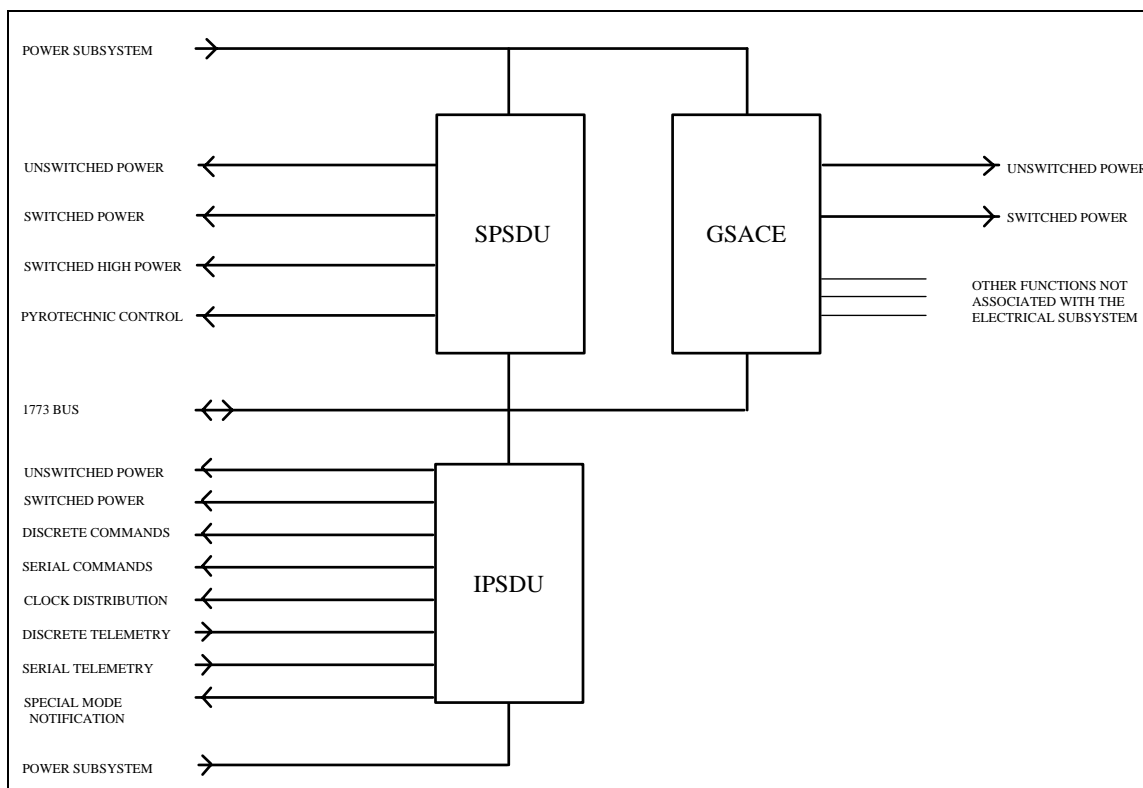


Figure 2.3-3 ACS Block Diagram

### 2.3.3 Electrical Subsystem

The Electrical subsystem provides power switching and distribution, optical command and telemetry routing, and discrete telemetry and command distribution. Pyrotechnics, launch vehicle interface support, and special test interfaces are also provided by the Electrical subsystem. The Electrical subsystem is comprised of two Power Switching and Distribution Units (PSDUs), power distribution modules located in the GSACE, and the electrical and optical harnessing. Figure 2.3-4 provides a block diagram of the Electrical subsystem. A more detailed description of the Electrical subsystem is included in section 4.3.



**Figure 2.3-4 Electrical Subsystem Block Diagram**

### 2.3.4 Power Subsystem

The Power subsystem is a Peak Power Tracking system consisting of two Super Nickel-Cadmium Batteries, four solar panels (mounted as two wings of two solar panels each), and the Power System Electronics (PSE). The Power subsystem provides 1100 watts of power and is connected directly to the Essential and Non-Essential Buses.

The PSE consists of the Power System Interface Box (PSIB), Standard Power Regulator Unit (SPRU) and the Power Bus Interface Unit (PBIU). The PSIB is a microprocessor based unit which provides the interface between the Power subsystem and the FDS. The PSIB also performs power subsystem monitoring and control functions such as individual Battery Cell

voltage monitoring and Amp Hour Integration control of the SPRU. The SPRU provides peak power from the solar array and charge control for the batteries using Voltage/Temperature and Constant Current Control circuitry. The PBIU contains the battery and bus relays and directs power to the Essential and Non-Essential busses. It also contains the battery and bus current shunts for monitoring current flow through the system. Figure 2.3-5 shows a block diagram of the Power subsystem. A description of the Power subsystem is provided in section 4.4.

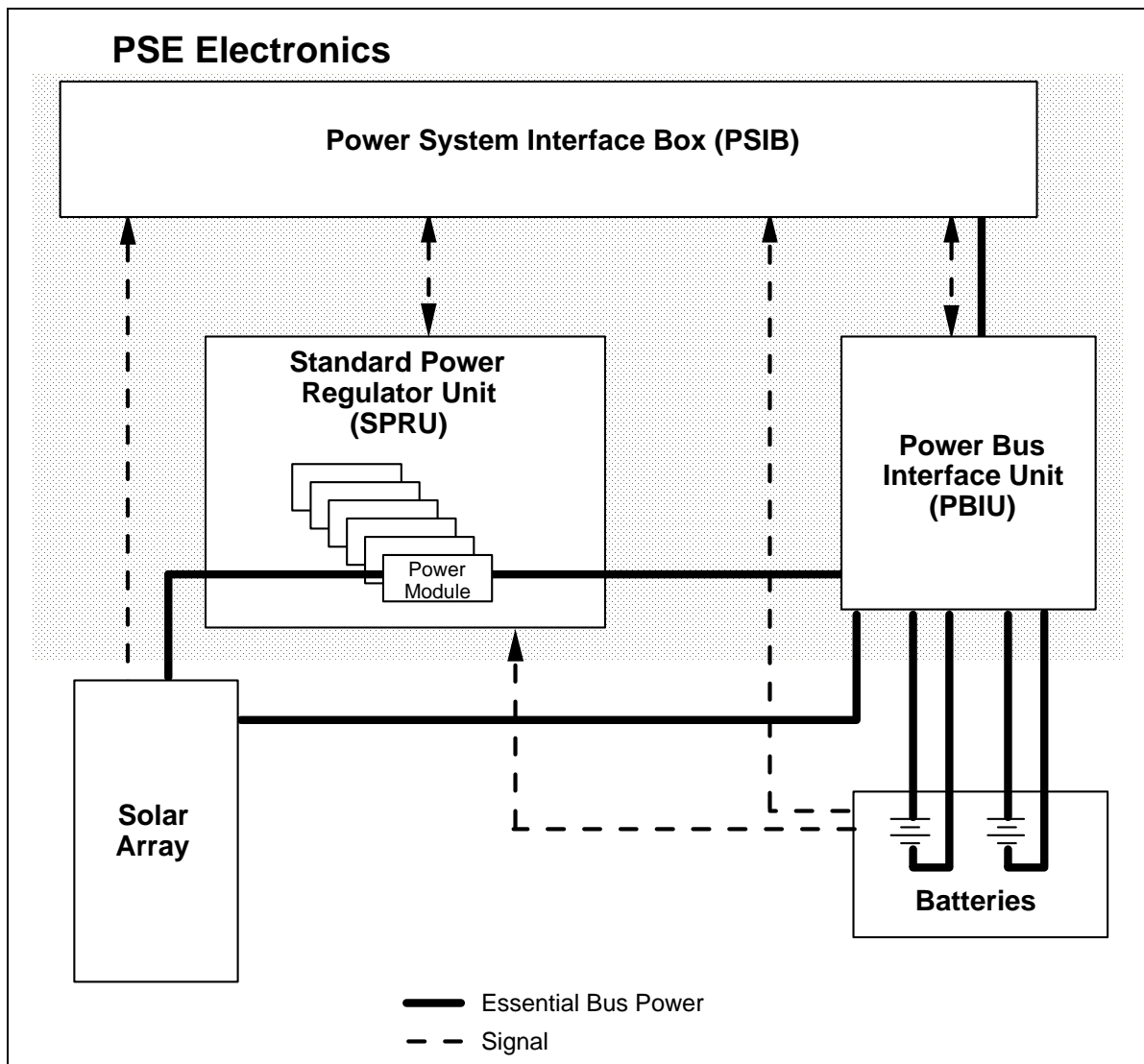
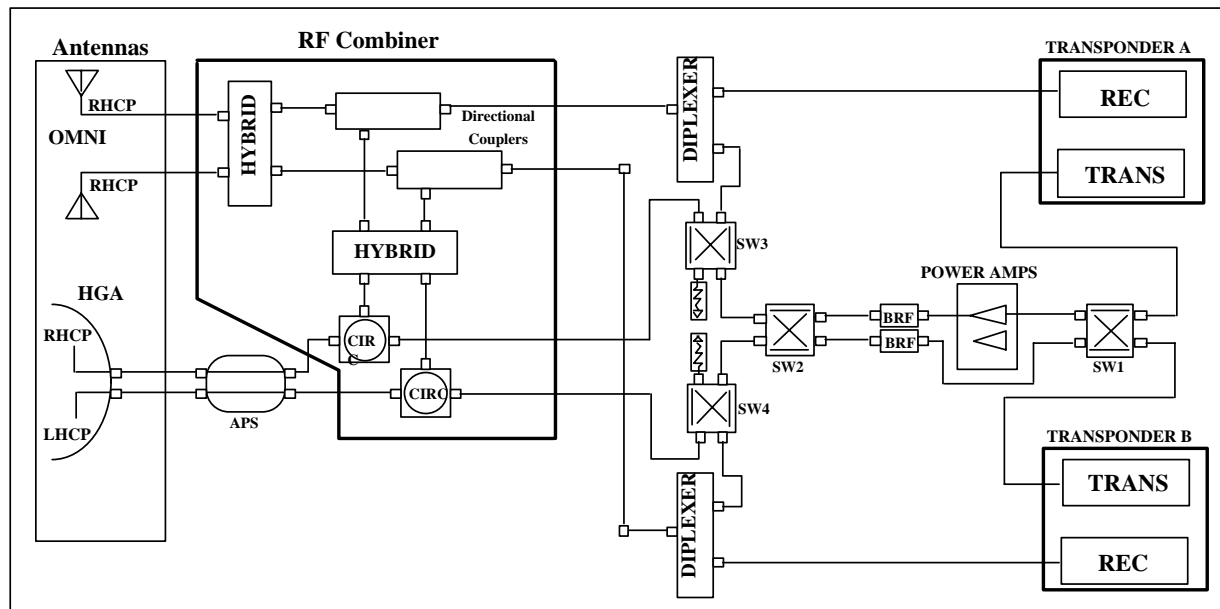


Figure 2.3-5 Power Subsystem Block Diagram

### 2.3.5 Radio Frequency (RF) Communications Subsystem

The RF Communications subsystem is designed to provide real-time communications through the TDRS Space Network (SN). This is accomplished by using the deployable HGA or the two Omni antennas. The HGA will provide nearly hemi-spherical coverage, and the Omni antennas

will also provide nearly spherical coverage. The TRMM design includes two NASA Standard Second Generation User Transponders. Figure 2.3-6 illustrates the RF subsystem for TRMM. A description of the RF subsystem is provided in section 4.5.



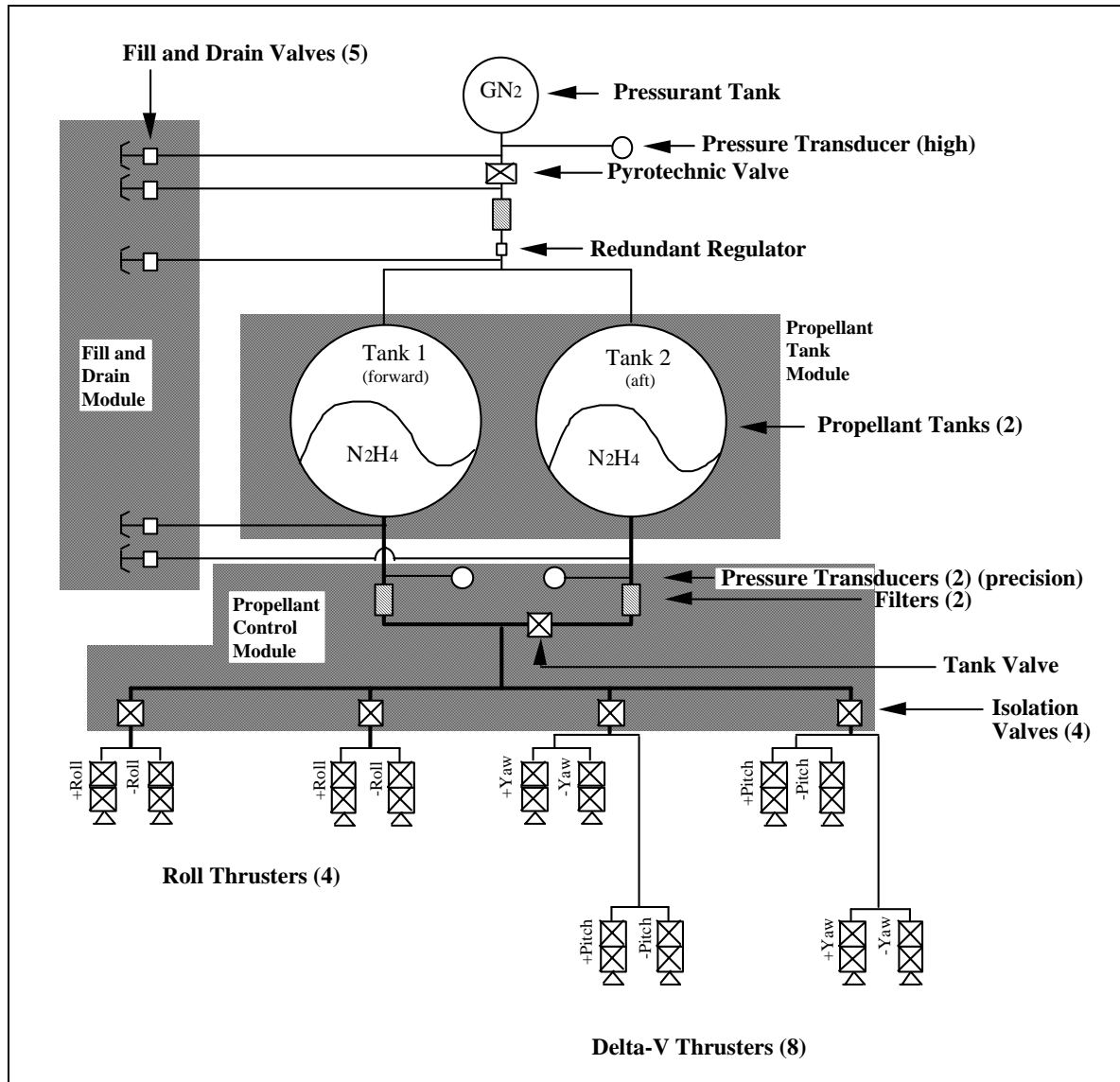
**Figure 2.3-6 RF Communications Subsystem Block Diagram**

### 2.3.6 Thermal Subsystem

The Thermal subsystem provides the components and equipment in order to maintain the thermal environment of the observatory during all mission modes. There are two types of components included in the Thermal subsystem design, passive and active components. Passive components include thermal blankets, louvers, heat pipes, thermal coatings, and some temperature sensors. Active components include heater elements, thermostats, and Solid State Temperature Controllers. A description of the Thermal subsystem is provided in section 4.6.

### 2.3.7 Reaction Control Subsystem

The RCS provides the propulsion capability required for orbit maintenance, attitude control during orbit maneuvers, and the safe end of life ocean disposal. The RCS also provides the capability to perform back-up momentum wheel unloading and yaw maneuvers. The implementation of either of these back-up capabilities requires two or more ACS component failures, and therefore no fuel has been budgeted for these capabilities. The RCS consists of twelve Rocket Engine Modules (REMs), five Fill and Drain Valves, Pressure Transducers, Regulators, the Propellant Control Module (PCM), Pressure Transducers, and the Propellant and Pressurant tanks. Figure 2.3-7 provides a functional block diagram of the RCS. A more detailed description of the RCS is provided in section 4.7.



**Figure 2.3-7 Reaction Control Subsystem Block Diagram**

### 2.3.8 Deployables

The TRMM Deployables consists of a High Gain Antenna Deployment and Pointing System (HGAD/PS), the Solar Array Deployment and Drive System (SADDS), and a Gimbal and Solar Array Control Electronics (GSACE) box.

The High Gain Antenna (HGA) will be utilized for normal telemetry communications, provides a 2-axis Pointing System (PS) for tracking, and a High Gain Antenna Deployment System (HGADS) to deploy and support the HGA and PS. The SADDS consists of two two-panel Solar Array (SA) wings and two Solar Array Drive Assemblies (SADA). The GSACE controls the

position of both the HGA pointing system and the SA rotary actuators in the SADA. Control of the HGA and SAs, as well as GSACE operations are described in section 4.2 and 4.8.

## 2.4 INSTRUMENT DESCRIPTION

The TRMM observatory includes five science instruments, namely the Precipitation Radar (PR), Visible and Infrared Scanner (VIRS), TRMM Microwave Imager (TMI), Clouds and Earth's Radiant Energy System (CERES), and the Lightning Imaging Sensor (LIS).

TRMM has three instruments (PR, TMI, and VIRS) in its rainfall measurement package, to obtain tropical and subtropical rainfall measurements, rain profiles, and latent heat release. TRMM has the only passive microwave instrument (TMI) in a low inclination orbit and the only rain radar (PR) in space. The three rain instruments will provide the most complete rain data set (to date) in order to generate climate models and perform severe storm studies.

The two additional instruments flown on-board TRMM are the CERES and LIS. CERES and LIS will be flown on board TRMM as instruments of opportunity for the Earth Observation System Program. The CERES instrument will measure the Earth's radiation budget, and the LIS instrument will investigate the global distribution of lightning. Section 5 provides additional details on the design and operational characteristics of the TRMM instruments.

### 2.4.1 Precipitation Radar

The Precipitation Radar (PR) is the primary instrument onboard TRMM. The most innovative of the five TRMM instruments, the PR is the first quantitative rain radar instrument to be flown in space. The major objectives of the PR instrument are as follows:

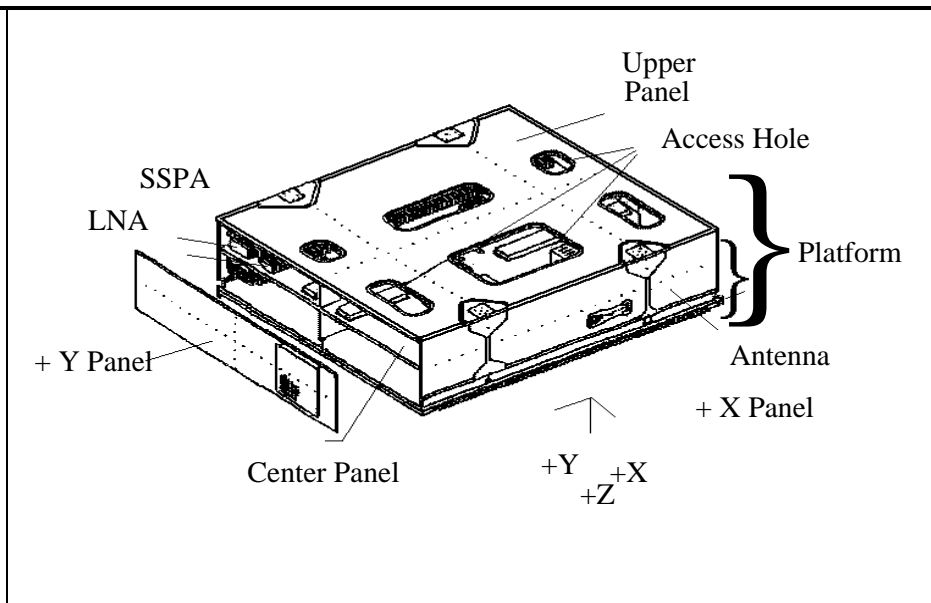
- a. to provide a 3-dimensional rain-fall structure
- b. to achieve quantitative measurements of the rain rates over both land and ocean

When properly combined with TMI measurements, the PR data will be instrumental in obtaining the height profile of the precipitation content, from which the profile of latent heat release from the Earth can be estimated. The rain rate will be estimated from the radar reflectivity factor when the rain rate is small by applying conventional algorithms used for ground-based radar. For large rain rates, a rain attenuation correction will be made using the total-path attenuation of surface echoes.

Figure 2.4-1 provides an illustration of the PR instrument. A more detailed description of PR instrument operations is provided in section 5.1.

### 2.4.2 Visible and Infrared Scanner

The VIRS instrument is a cross-track scanning radiometer which measures scene radiance in five spectral bands, operating in the visible through infrared spectral regions. VIRS is similar to instruments flown on other NASA and NOAA meteorological satellites. Comparison of the microwave data with VIRS visible and infrared data is expected to provide the means whereby precipitation will be estimated more accurately than by visible and infrared data alone. The VIRS instrument will serve as a background imager and will provide the cloud context within



which the passive microwave and radar observations are made. Data from the VIRS instrument will be used in rain estimation algorithms based primarily on the passive and active microwave sensors.

The VIRS instrument possesses a radiative cooler, a Solar Calibrator door, an Earth Panel shield, and a Solar Panel shield. The Earth panel shield will be deployed to block the Earth's reflection, and the Solar Panel shield will prevent the Sun from shining into the VIRS. A detailed description of VIRS instrument operations is provided in section 5.2.

**Figure 2.4-1 PR Instrument Diagram**

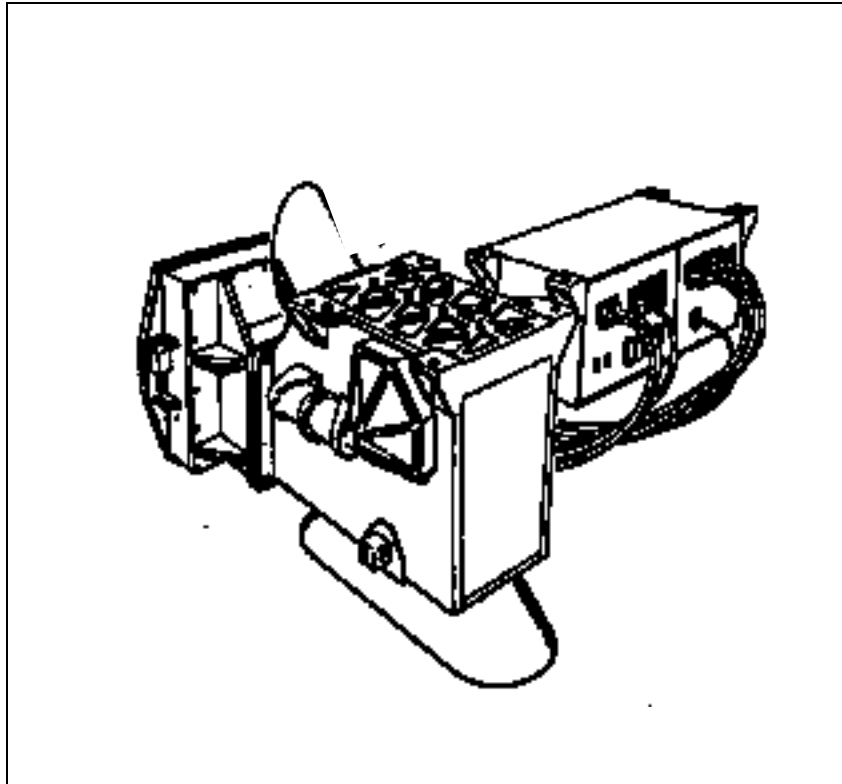


Figure 2.4-2 VIRS Instrument Diagram

### 2.4.3 TRMM Microwave Imager

The TRMM Microwave Imager (TMI) is a Multi-channel dual-polarized passive microwave radiometer. TMI utilizes nine channels with operating frequencies of 10.65 GHz, 19.35 GHz, 21.3 GHz, 37 GHz, and 85.5 GHz. The TMI instrument will provide data related to the rainfall rates over the oceans, but less reliable data over land, where non-homogeneous surface emissions make interpretation difficult. The TMI instrument is similar to the SSM/I instrument currently in orbit on the Defense Meteorological Satellite Program spacecraft. The TMI data combined with the data from the PR and VIRS will also be utilized for deriving precipitation profiles.

The TMI instrument has a single operational mode and no commandable redundancy. Accordingly, command procedures are minimal and will focus on power and heater control. TMI essentially has two modes, OFF and ON. Two external calibrators on the stationary shaft are used to perform calibrations during each instrument rotation (scan). The instrument will spin at a rate of 31.6 RPM. Each scan begins with 130° of scene data, followed by a cold reference measurement and then a hot load reference measurement. These reference measurements, along with the known temperatures of the calibration loads, serve to calibrate the scan. Figure 2.4-3 provides a graphical illustration of the TMI instrument. A detailed description of TMI instrument operations is provided in section 5.3.

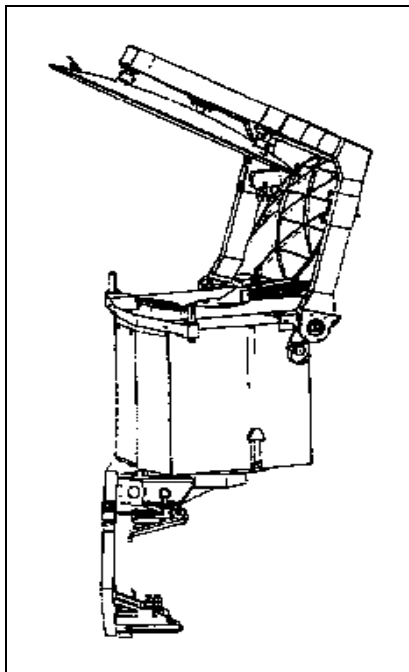


Figure 2.4-3 TMI Instrument Diagram

### 2.4.4 Clouds and Earth's Radiant Energy System

The CERES experiment will help reduce one of the major uncertainties in predicting long-term changes in the Earth's climate: How do clouds affect the flow of radiant energy through the

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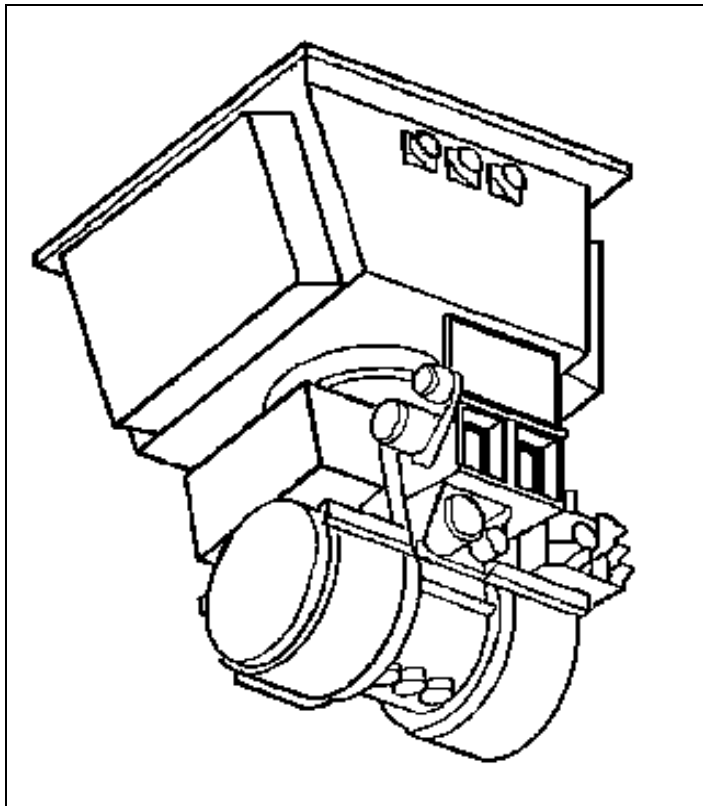
Earth-atmosphere system. Radiant fluxes at the top of the Earth's atmosphere (TOA) were measured by the Earth Radiation Budget Experiment (ERBE), not merely as an undifferentiated field, but with reasonable separation between fluxes originating from clear and cloudy atmospheres. It was also discovered from ERBE that clouds have a greater affect on the TOA fluxes than was previously believed, but details of the process are not yet fully understood. The CERES experiment will attempt to provide a better understanding of how different cloud processes, such as convective activity and boundary-layer meteorology, affect the TOA fluxes. This understanding will help determine the radiative flux divergence, which enters directly into physically based, extended-range weather and climate forecasting. CERES will also provide information to determine the surface radiation budget, which is important in atmospheric energetics, studies of biological productivity, and air-sea energy transfer.

Figure 2.4-4 provides a graphical illustration of the CERES instrument. A detailed description of CERES instrument operations is provided in section 5.4.

### 2.4.5 Lightning Imaging Sensor

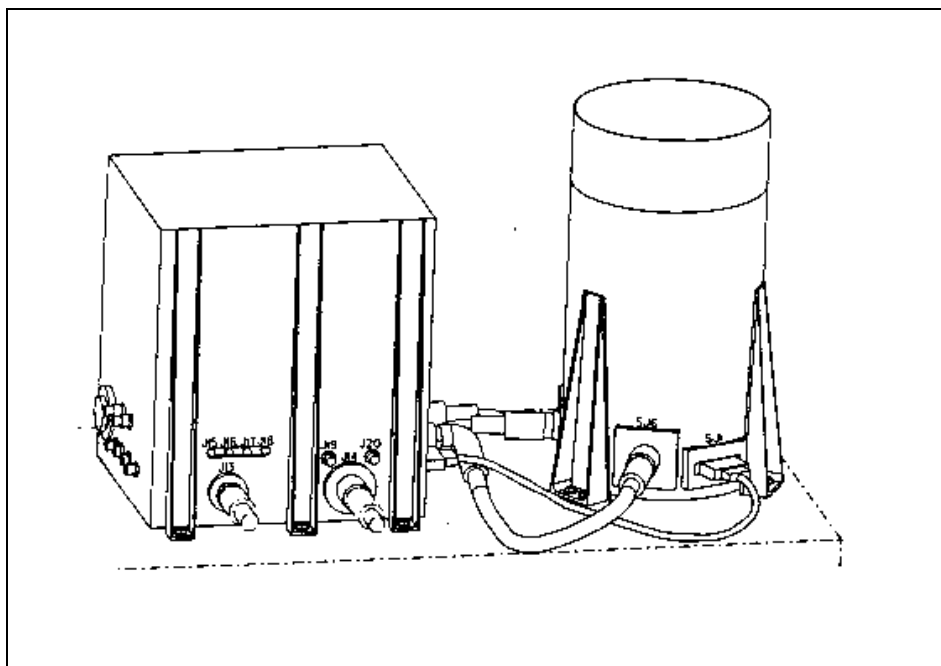
The LIS is a staring optical telescope and filter imaging system which will acquire and investigate the distribution and variability of both intracloud and cloud-to-ground lightning over

the Earth. The LIS data will also be used with PR, TMI and VIRS data to investigate the correlation of the global incidence of lightning with rainfall and other storm properties.



LIS is a single string instrument with multiple single points of failure. The LIS instrument will be powered ON during the initial instrument activation, and will remain powered in that configuration for the duration of the mission (barring any unforeseen anomalous conditions). Figure 2.4-5 provides a graphical illustration of the LIS instrument. A detailed description of LIS instrument operations is provided in section 5.5.

**Figure 2.4-4 CERES Instrument Diagram**



**Figure 2.4-5 LIS Instrument Diagram**

## **2.5**

### **GROUND DATA SYSTEM OVERVIEW**

The means whereby the mission can conduct its science data capture and dissemination activities is provided through the Code 500 Mission Operations and Data Systems Directorate (MO&DSD). A combination of GSFC institutional and mission unique elements comprise the TRMM Ground Data System (GDS). The focal point for mission operations is the TRMM Mission Operations Center (MOC). From here, the TRMM FOT will conduct real-time and off-line activities required to support the mission. Figure 2.5-1 provides a functional diagram of the TRMM Ground System.

The following sections provide a brief functional description of the ground system elements supporting TRMM.

#### **2.5.1**

##### **Mission Operations Center**

The TRMM MOC, located in Building 32 at GSFC, is developed by the Mission Operations Division (MOD), Code 510. It provides the hardware and software systems necessary for the successful conduct of real-time and off-line activities. From here, the FOT will ensure that spacecraft conditions are monitored and controlled, and that science data capture is maximized. The MOC will facilitate TDRS scheduling and will provide the appropriate interfaces to interact with the elements required to conduct mission operations. For more specific details with respect to the MOC facility, reference section 6.1.

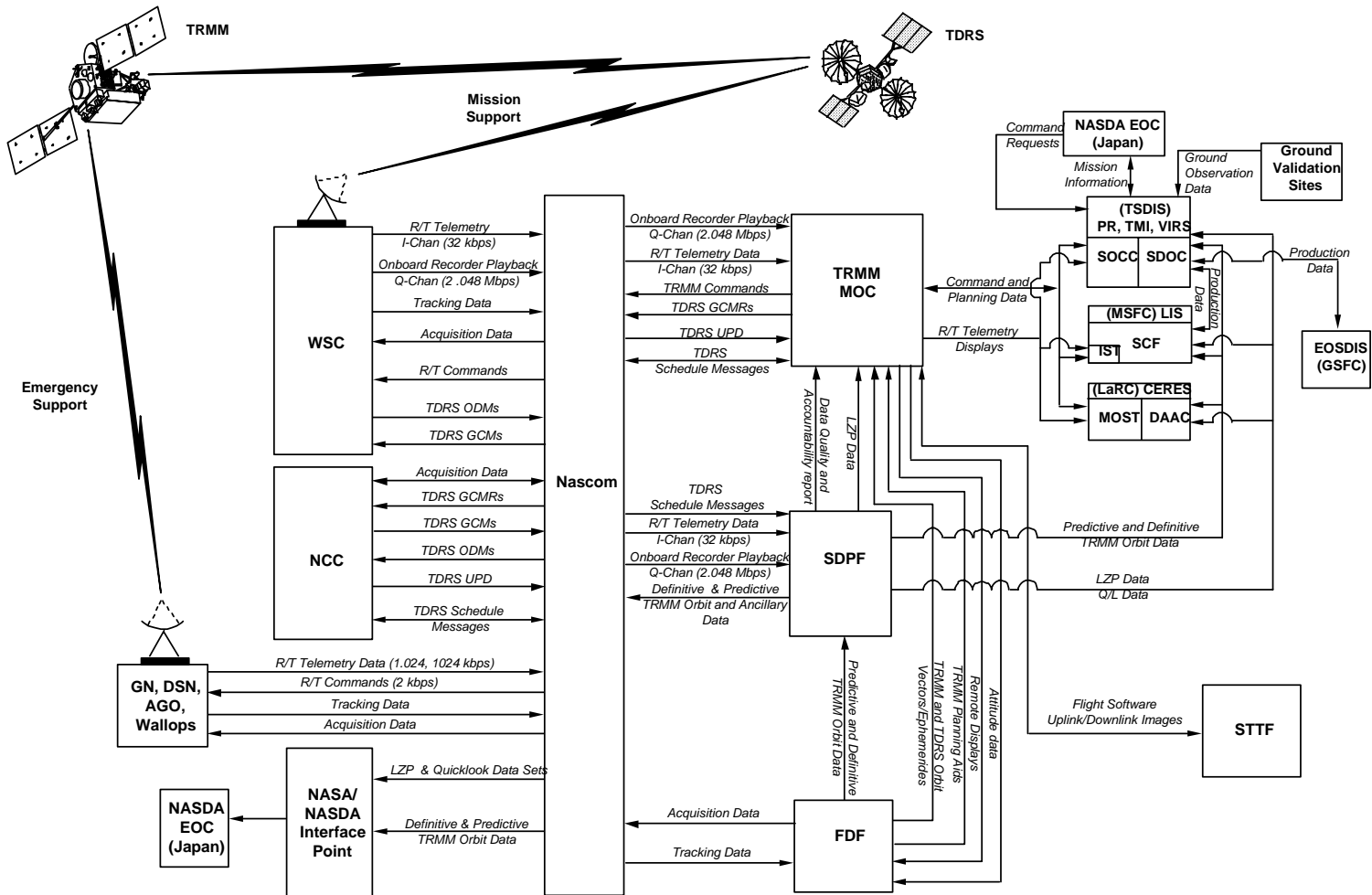


Figure 2.5-1 TRMM Ground System Functional Diagram

**2.5.2 TRMM Test & Training Simulator**

The Simulations and Compatibility Test Branch, Code 515, will provide the TRMM Test and Training Simulator (TTTS) to support pre-launch tests and training efforts. The TTTS is a medium-fidelity simulator, providing a capability to exercise the MOC and other ground system elements and to aid in the training of the FOT. As a medium-fidelity simulator the TTTS will emulate most C&DH functions including command validation, stored command processing, and telemetry formatting, as well as simulate selected subsystems. The TTTS will interleave ACS and ACE data provided by the Hybrid Dynamic Simulator (HDS), and instrument data provided by the science facilities and/or the TRMM Integration and Test (I&T) team. For a more detailed description of the TTTS, reference section 10.3.

**2.5.3 NASA Communications**

Nascom, Code 540, serves as the hub for data and voice communications amongst the supporting elements of the mission. Data and voice links required to accomplish all real-time and off-line activities, from pre-launch testing throughout the mission lifetime will be provided by Nascom. In addition to institutional services, data and/or voice activities to external science agencies (TSDIS, LaRC, MSFC, and NASDA EOC) will be provided and maintained by Nascom. For specific details with respect to Nascom operations, refer to section 8.4.

**2.5.4 Network Control Center**

The NCC is an institutional element of the MO&DSD, developed and operated under the Networks Division, Code 530. The NCC provides all Spaceflight Tracking and Data Network (STDN) scheduling, configuration control, performance monitoring, and real-time operations support. This includes all network elements of the Space Network (SN), Ground Network (GN), and the Deep Space Network (DSN).

**2.5.5 Flight Dynamics Facility**

The FDF is an institutional element of the MO&DSD, developed and operated under the Flight Dynamics Division (FDD), Code 550. The FDF provides orbit determination, onboard attitude control performance assessments and sensor calibrations, orbit and attitude maneuver support, TRMM tracking data processing for computation of orbit position, TRMM Transponder center frequency measurements, and planning/scheduling product generation. While these items may be considered off-line or non real-time activities, the FOT will ensure that selected attitude parameters from the real-time telemetry stream are forwarded to the FDF. The FDF facility will also be equipped with a MOC remote display capability. For specific details with respect to the FDF facility, reference section 8.1.

**2.5.6 Software Test and Training Facility**

The STTF will provide long term flight software maintenance as related to memory images, dumps, and system tables. The interface to the MOC will be via the OBC Support Tools (OST)

PC, located in the MOC. The STTF will provide flight software maintenance support for the FDS, ACS (including the ACEs), and PSIB processors. The STTF is a Project provided facility, located in Building 1. The personnel staffing the STTF are referred to as the Flight Software Systems Branch (FSSB) and are provided by Code 512. The STTF will also be used for development and testing of all post-launch flight software (ACS, FDS, and PSIB) modifications.

Additionally, the STTF will be equipped with a C&DH Engineering Test Unit (ETU), an ACS hybrid dynamic simulator (HDS), and various remote terminals (RTs). The STTF will also be equipped with a Programmable Data Formatter (PDF) and Nascom lines to allow an interface to the TRMM MOC. This facility will provide a high-fidelity simulation capability, to accommodate FOT training. The STTF will be used by the FOT (as a shared resource) to perform various load/dump operations, maneuver simulations (Delta-V and Yaw), and Safe-Hold operations. For a more detailed description of STTF operations, refer to section 10.3.

### **2.5.7 Sensor Data Processing Facility**

The SDPF is an institutional element of the MO&DSD, developed and operated by the Information Processing Division, Code 560. The SDPF will provide Level-0 and Quicklook processed data sets and archival of mission data for 2-years (archival of raw data at the Block level). The SDPF will also provide real-time telemetry to the launch site (for 30 - 45 days after launch), for housekeeping telemetry monitoring by the subsystem engineers. For specific details with respect to SDPF operations, reference section 8.3.

### **2.5.8 TRMM Science Data and Information System**

The TSDIS operates under Code 900, the Earth Sciences Directorate, at GSFC, and provides instrument science data processing, and distribution support for the PR, VIRS and TMI instruments. The TSDIS includes a Science Data Operations Center (SDOC) and Science Operations Control Center (SOCC). The SDOC receives TRMM data (Level-0 and Quicklook processed data sets, ancillary and definitive/predictive orbit data ) from the SDPF, which it uses to generate higher level science data products. The SDOC also contains the data storage and DataBase capabilities for TSDIS. The SOCC assists the Instrument Scientists for VIRS and TMI in monitoring the "performance" of their instruments (i.e. trending of the science data and some engineering data as opposed to limit checks). The SOCC will also possess a MOC remote terminal interface for the monitoring of instrument health and safety. For specific details with respect to TSDIS operations, reference section 9.1.

### **2.5.9 NASDA Earth Observation Center**

The NASDA EOC receives Level-0 and Quicklook data products from the SDPF, provides PR science data processing, PR instrument mission planning and scheduling activities, and will assist in PR anomaly detection and resolution. The FOT's interface for PR operations will be via the TSDIS SOCC. The TSDIS SOCC will interface directly with the NASDA EOC personnel, and will relay any PR command and planning information to the FOT. For specific details with respect to the EOC facility, reference section 9.2.

**2.5.10                      Langley Research Center**

LaRC will be responsible for the CERES instrument, although daily instrument operations will be managed by the FOT. A real-time telemetry monitoring capability will be provided at the LaRC CERES Instrument Monitoring System while data handling from the SDPF will be the responsibility of the LaRC Distributed Active Archive Center (DAAC). LaRC will possess a MOC remote terminal interface to allow monitoring of the CERES instrument health and safety. For specific details with respect to the LaRC instrument operations facility, reference section 9.3.

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**2.5.11 Marshall Space Flight Center**

MSFC will be responsible for the LIS instrument. A real-time telemetry monitoring capability will be provided at the MSFC LIS Instrument Support Terminal while data handling from the SDPF will be the responsibility of the LIS SCF. MSFC will possess a MOC remote terminal interface for the monitoring of instrument health and safety. For specific details with respect to the MSFC instrument operations facility, reference section 9.4.

**2.5.12 Space Network**

The SN is the term given to the elements which comprise the real-time support network utilizing the TDRS communications satellite. The TDRS spacecraft, along with its ground terminal, is used for the throughput transmission of telemetry and command data to and from the MOC. Personnel at the ground terminal will assist (through the NCC) during anomalous communications conditions. All nominal real-time supports will be accomplished via the SN. TRMM data will be forwarded to the MOC in TDRS 4800-bit Nascom block format. For specific details with respect to the SN, reference section 8.5.

**2.5.13 Ground Network**

The GN comprises the Merritt Island (MILA) and Bermuda (BDA) tracking stations. The GN will be used for contingency operations during the L&IOC phase of the mission. In addition, the GN will be available (8-hours per day, Monday through Friday) for contingency support throughout the mission. The GN sites will support real-time telemetry only, and will not receive any playback data. TRMM data will be forwarded to the MOC in Digital Data Processing System (DDPS) 4800-bit Nascom block format. For specific details with respect to the GN reference section 8.6.

**2.5.14 Deep Space Network**

The DSN consists of three ground tracking stations and will be used for contingency support during the L&IOC phase of the mission. The tracking stations of the DSN are managed by the Jet Propulsion Laboratory (JPL). The three tracking stations of the DSN are Goldstone, California (D16), Canberra, Australia (D46), and Madrid, Spain (D66). All scheduling of DSN supports will be through the JPL. If necessary, the DSN will also be available for contingency support throughout the mission. In the event of an anomaly, real-time and playback telemetry data will be downlinked via the DSN. Real-time telemetry will be stripped-and-shipped to the MOC, in real-time, and recorder playback data will be stored on-site for post-pass playback (to the MOC and SDPF). TRMM data will be forwarded to the MOC in 4800-bit Nascom DSN/GSFC Interface Block (DGIB) format. For specific details with respect to the DSN reference section 8.6.

**2.5.15 Santiago Tracking Station**

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The Santiago (AGO), Chile ground tracking station will be used for contingency support during the L&IOC phase of the mission. In addition, AGO will be used for contingency support throughout the mission. In the event of an anomaly, real-time and playback telemetry data will be downlinked via AGO. Real-time telemetry will be stripped-and-shipped to the MOC, in real-time, and recorder playback data will be stored on-site for post-pass playback (to the MOC and SDPF). TRMM data will be forwarded to the MOC in DDPS 4800-bit Nascom block format. For specific details with respect to the AGO reference section 8.6.

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**2.5.16 Wallops Flight Facility**

The ground tracking station at the Wallops Flight Facility (WFF), Virginia, will be used for contingency support during the L&IOC phase of the mission. In addition, WFF will be used for contingency support throughout the mission. In the event of an anomaly, real-time and playback telemetry data will be downlinked via WFF. Real-time telemetry will be stripped-and-shipped to the MOC, in real-time, and recorder playback data will be stored on-site for post-pass playback (to the MOC and SDPF). TRMM data will be forwarded to the MOC in DDPS 4800-bit Nascom block format. For specific details with respect to the WFF reference section 8.6.